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# FATS AND EMULSIFIERS IN FEEDING BROILER CHICKENS
(review)

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Abstract

The increase in feed prices determines the need to optimize the rationing of high-energy ingredients of the diet, as well as various approaches to improving the efficiency of their use in the digestive process. In industrial poultry farming, fats, having a high energy value, serve as indispensable components of the diet (V.I. Fisinin et al., 2000; V.I. Fisinin et al., 2011). They provide high productivity and economic efficiency (N.C. Baião et al., 2005; M. Nayebpor et al., 2007; H. Fébel et al., 2008), play an important role in the regulation of metabolism, deposit energy, performing a protective function, serve as solvents and carriers of vitamins, hormones, as well as an obligatory component of nervous tissue (A.V. Arkhipov, 2010; M. Poorghasemi et al., 2013; R. Rodriguez-Sanchez et al., 2019). A wide variety of fats and oils and by-products of processing are available for use in diets, for example, animal fats and vegetable oils (soy, corn, sunflower, palm, hemp, mustard, etc.), sunflower fusel (a by-product of the conversion of sunflower seeds into vegetable oil), acidified soapstocks (by-products refining of vegetable oil, mainly containing free fatty acids), hydrogenated fats (A.V. Arkhipov, 2007; V.A. Manukyan et al., 2018; L.N. Skvortsova et al., 2013). The choice of fat for use in feeding farm animals and poultry is largely determined by both its cost and quality characteristics. The main factor that affects the release of energy from fat entering the body with food is its digestibility (V. Ravindran et al., 2016; R. Rodriguez-Sanchez et al., 2019; B. Jimenez-Moya et al., 2021). The digestion of fats is a complex process that requires a sufficient amount of bile acid salts and enzymes (S. Leeson et al., 2009). In addition, the correction of the diet with lipids is effective, but economically impractical. The increase in prices for animal and vegetable fats currently encourages interest in the search and use of alternative energy sources in the feed of farm animals or substances that enhance the processes of digestion and assimilation of lipids, in order to reduce the cost of production (S.A. Miroshnikov et al., 2005; O. Lyutykh, 2020). One of the approaches to increase the amount of available fats can be the use of synthetic and natural emulsifiers. Popular emulsifiers usually consist of hydrophilic and hydrophobic components that can reduce the surface tension of fat and water, reduce chylomicrons of fat, improve emulsification and increase fat absorption, make up for the deficiency of bile acid and lipase in the digestive tract of poultry (M. Rovers et al., 2014; M. Jansen et al., 2015). Natural emulsifiers include bile acids and salts, including cholic and henodeoxycholic, taurocholate, lecithin, casei, phosphatide concentrates, some of which can be produced in the animal's body (M. Soares et al., 2002). Bile acid salts reduce the tension of the oil-water interface, activate pancreatic lipase, and also prevent the denaturation of this enzyme when it throws the surface of emulsified fat droplets (M. Boesjes et al., 2014; Y. Xu, 2016; X.K. Ge et al., 2019). Synthetic emulsifiers (lysolecitin, lysophosphatidylcholine, mono- and polyoxyethylene glycol dioleates) improve liver and bile duct function, accelerate weight gain and improve feed conversion, increase growth rates and nutrient digestibility (B. Zhang et al., 2011; M.M. Gheisar et al., 2015; S.D. Upadhaya et al., 2018). Consequently, the strategy of using emulsifiers and enzymes can be an effective tool for improving the digestion of fats both in young birds with functional immaturity of the digestive system and in adults to further reduce feed losses due to the intensification of the digestive process. The use of this approach will provide increased digestibility and digestibility of nutrients while reducing the introduction of vegetable and animal fats into the diet of broiler chickens.

Keywords: chicken broilers, feeding, diet, fats, oils, lipids, emulsifiers, digestion, microbiome

Currently, industrial poultry farming is an example of an efficient meat production system among other livestock industries [1, 2]. The main condition for the successful development and good productivity of poultry is a full-fledged rationed feeding [3, 4]. Since the formation of the body occurs due to the nutrients of the feed (proteins, fats, carbohydrates, minerals and vitamins), the rate of growth and development, body weight and productivity are directly dependent on the component composition of the diet and its percentage ratio [5-7].

The term “fat” is commonly used as a synonym for lipid. Both terms describe a variety of compounds that are insoluble in water but soluble in organic solvents such as chloroform, acetone, alcohol, and diethyl ether. Lipids play an important role in the nutrition, biochemistry and physiology of animals. From a nutritional perspective, triglycerides, phospholipids, sterols, and fat-soluble vitamins are important [8].

Rising feed costs have led to an increased interest in the use of fat supplements in the diet. The inclusion of fat in diets has become a widespread practice in the poultry industry to meet the high energy requirements of fast growing birds [9-12]. Essential fatty acids and vitamins also enter the body along with fat [8, 13, 14]. However, there are some problems with fat intake, quantity and digestibility in broiler chickens. Fat digestibility depends on the age of the bird, as well as the type and source of fat [15].

Free fatty acids released during the digestion of fats can react with divalent cations to form soluble or insoluble soaps. In case of formation of insoluble soap, fatty acids and minerals can become unavailable to the birds. The divalent $Ca^{2+}$ ions present in the feed bind to fatty acid molecules and result in the formation of soap that is not absorbed or digested, resulting in loss of fat and calcium [16]. Dietary fats also affect the digestibility, absorption, intake, and metabolism of many other substances, such as carbohydrates, proteins, and minerals [17]. There is a relationship between carcass fat content and the type of fat in feed [18]. Some fats used in the diet cause more abdominal fat and lead to the rejection of such a product by consumers in the markets.

An alternative to increasing the amount of fat in diets can be synthetic and natural emulsifiers that intensify its digestion. This approach will provide increased digestibility and absorption of nutrients while reducing the amount of vegetable and animal fats introduced into the diet.

The purpose of this review is to assess the effectiveness of the use of various sources of fat in the diet, to analyze the causes that affect the rate of digestion and absorption of fats, and also to compare ways to control these processes using various substances, including emulsifiers.

*The role and properties of fats.* The central place in the theory of feeding broiler chickens is occupied by energy nutrition, primarily the content of metabolic energy in the diet. The key condition is a significant increase in the amount of energy used to synthesize products (19). Optimal energy content in the diet ensures high protein conversion. The lack of energy leads to the fact that amino acids begin to be used for energy purposes, which reduces the productivity of broiler chickens. It is important to note that fat synthesis uses the energy of digested protein to a lesser extent than the energy of digested carbohydrates and fats [20, 21].

The biological functions of lipids are diverse: they serve as the main form of energy storage in the body, sources of essential fatty acids, structural components of biological membranes, and the basis for the subsequent synthesis of some biologically active substances [22-25]. Fats can improve the physical properties and palatability of feed, thus increasing feed intake [26, 27].

Along with fats, carbohydrates and proteins serve as energy components of the diet [28]. Fats can be synthesized in the body from carbohydrates (25.2 g of fat is produced from 100 g of starch) and proteins (26 g of fat is synthesized from 100 g of protein) [29]. However, in terms of energy capacity, carbohydrates and proteins differ slightly, while the energy saturation of fats is much higher, approx. 2.25-fold. The energy value of 1 g of fat is approximately equal to 9.3 kcal, or 39 kJ, and when 1 g of carbohydrates are oxidized, 17 kJ is formed, and 1 g of proteins is 24 kJ. In addition to the fact that fat is the main energy store, it also acts as a structural material in the cell and is necessary for the normal functioning of the digestive glands.

Fats are involved in the regulation of metabolism [30-32], perform a protective function (due to deposition in the area of internal organs and in subcutaneous adipose tissue) [33, 34], dissolve and transfer vitamins and hormones, and are also part of the nervous system tissues [35, 36].

A wide variety of fats and oils are available for use in diets, including by-products of processing, such as animal fats and vegetable oils (soybean, corn, sunflower, palm, hemp, rapeseed, etc.), sunflower fuse (a by-product of seed processing into vegetable oil), hydrogenated fats, and acidified soapstocks (free fatty acids are removed from the alkaline refining process and precipitated as alkaline soaps) [23, 25, 29]. These fats and oils vary considerably in composition. The choice of fat for feeding farm animals and poultry is largely determined by both its cost and quality characteristics.

The main factor that affects the release of energy from fat that enters the body with food is its digestibility. The digestibility of fats and oils is affected by many factors. These include the number of double bonds, or the degree of unsaturation of the fatty acid, the amount of free fatty acids and their position in the triglyceride molecule, the structure of the diet, the sex and age of the bird, and the composition of the intestinal microflora [8, 37, 38].

The nutritional value of fats depends on both their energy potential and safety. Oxidation becomes the main reason for the loss of quality of fat. Oxidative rancidity is a process that occurs in unsaturated fatty acids when the double bond of triglycerides is oxidized. It affects smell, color and taste and ultimately reduces the value of fat [39].

Currently, the use of liquid vegetable oils as sources of fats, which differ in the ratio of saturated and unsaturated fatty acids, is justified. This circumstance determines the digestibility and use of fats by poultry. In addition, these foods serve as an additional source of essential fatty acids [40].

Thus, fats, having a high energy value, are indispensable components of the diet. Lipids play an important role in the regulation of metabolism, store energy, perform the protective function of the body, serve as solvents and carriers of vitamins, hormones, prostaglandins, and are also an essential part of the nervous tissue.

Fats in the diet of broiler chickens and their regulation. In Russia, the dietary structure of broiler chickens is predominantly based on a wheat or wheat-barley feed mixture, which makes diets energy deficient [41]. In connection with the increase in the price of grain feed in recent years, the addition of fat to the diets of farm animals has become a necessary measure. Since the energy released during the digestion of fats is higher than the energy of carbohydrates, it makes economic sense to increase the fat content in broiler diets. In case of a lack of fats, metabolic processes, liver functions are disturbed, there is a lack of vitamins A, D, E, K, skin diseases (dermatitis, plumage disorders) occur, as a result, immunity decreases and reproductive function disorders occur [42, 43].

According to the instructions of the All-Russian Research and Technological

Institute of Poultry Farming (2010), the recommended dosage of fats and oils in feed is 4-6%, which positively affects productivity, the use of feed nutrients and metabolism, including lipid (Table 1). However, since the oil content directly affects the structure and granulation of the feed, other authors recommend introducing no more than 4% [5, 43].

**1. Metabolized energy, protein, fat, linoleic acid, unsaturated and saturated fatty acids in the diets of broiler chickens [1]**

| Weeks of growth | Metabolized energy, kJ/100 g | Crude protein, % | Linoleic acid, % | Fats and oils, % | Fatty acids, % | |
|---|---|---|---|---|---|---|
| | | | | | unsaturated | saturated |
| 1-3 | 1297 | 23.0 | 1.4 | 0-6 | 100 | 0 |
| 4-5 | 1318 | 21.0 | 1.3 | | 75 | 25 |
| 6-7 | 1339 | 20.0 | 1.2 | 0-8 | 50 | 30 |

In young chicks, fat digestion and absorption is inefficient due to low natural lipase production [24]. Activity and net duodenal lipase secretion increase with age [44]. The problem is exacerbated by the low rate of bile salt synthesis in juveniles [45]. However, these physiological features are leveled with age. In this regard, for broiler chickens, the proportion of fat in the diet in the first 10-14 days is limited to 2.5-3.0% [45-48].

The main factor in the digestibility of fats and oils by the body is the content of saturated and unsaturated fatty acids in them. Animal fats consist mainly of saturated fatty acids, while vegetable fats consist of unsaturated fatty acids. Unsaturated fatty acids ensure normal growth, metabolism, proper skin function, vascular elasticity, and cholesterol metabolism in the body [49-51]. Excess leads to lipid peroxidation, metabolic disturbances, reduced productivity and reproductive function of poultry, as well as to the destruction of fat-soluble vitamins, especially vitamins A and E [52, 53]. From vegetable oils, sunflower and rapeseed oils, less often linseed and palm oils are used as lipid additives [54].

Vegetable oil is an easily accessible source of metabolic energy. Its nutritional value depends on the content of fats and vitamins, in particular polyunsaturated fatty acids (PUFAs) (linoleic 50-60%). Vegetable oils also serve as sources of vitamin E and β-carotene [55]. In Russia, sunflower oil is mainly used as a lipid supplement in feeding broiler chickens. However, given the high content of linoleic acid in it (in the diet no more than 1.8%), which negatively affects productivity, its use is limited.

Linoleic and α-linolenic acids are recognized as metabolically essential fatty acids. Linoleic acid is the only essential fatty acid that has been proven necessary. Linoleic acid deficiency is rare. With a shortage, there is an increased need for water and a decrease in the immune response. Linoleic acid deficiency in bettas can impair spermatogenesis and affect fertility [56]. Insufficient deposition of linoleic acid in the egg will adversely affect embryonic development [57]. The essential fatty acid requirements of growing and adult birds can usually be met by feeding a diet with 1% linoleic acid. Oils of rapeseed, hemp, flax and camelina are rich in linoleic acid [23]. The need for poultry in -linolenic acid has not yet been proven. However, α-inolenic acid plays an important role in the development of specialized membranes in the retina and nervous system [58].

In contrast to Russia, in the United States, corn is the basis of compound feed, a high-energy product that significantly increases the energy of the diet [59]. The energy intake of broiler chickens can vary with age, rearing stage and ambient temperature and is typically between 400 and 450 kcal IU per head per day (or 1640-1845 kJ) [59]. Auxiliary energy components are usually rapeseed oil, animal and palm fat [60].

Thus, the use of vegetable fats in feeding birds, on the one hand, is necessary to ensure the physiological process, on the other hand, it is an effective way to increase the energy value of the feed.

Digestion of fats. Digestion and absorption of fat occurs in several steps and includes emulsification (fat breakdown into droplets), hydrolysis by pancreatic lipase and formation of mixed micelles, as well as movement of micelles to the intestinal epithelium and absorption [61].

Digestion of fat is greatly accelerated when it enters the duodenum. Bile, formed in hepatocytes, passes into the gallbladder, and then into the intestine in the duodenum [64]. It contains bile pigments, bile salts, phospholipids, cholesterol, electrolytes and some proteins. Bile salts and phospholipids are the major components of bile required for lipid digestion [65]. In poultry, bile salts combine with taurine in the liver, which increases their water solubility and also reduces the cellular toxicity of bile salts. Bile salts are flat amphiphilic molecules, one side of which is a non-polar hydrophobic surface and interacts with water, and the other side is a polar hydrophilic surface that interacts with the oil phase of the emulsion. Due to this unique characteristic, bile salts are at the water-lipid interface and do not penetrate deeply [66].

This step promotes emulsification and activates pancreatic lipase, and prevents denaturation of lipase as it leaves the surface of the emulsified fat droplets [65]. Feed fat enters the intestine in the form of rather large coagulated particles. The presence of bile has a detergent-like effect on dietary lipids, causing this coagulated mass to break up into very fine, stable droplets (i.e., preventing sticking) and increasing the total surface area for lipase action [58].

Lipase is one of the digestive enzymes secreted by the pancreas, including trypsin, chymotrypsin, amylase, and phospholipases. The enzyme acts as a catalyst only when it is on the surface of emulsified fat droplets along with bile salts and co-lipase, a cofactor present in pancreatic juice. By itself, co-lipase has no enzymatic activity, but is required to initiate the activity of pancreatic lipase. Colipase is rich in both hydrophobic and hydrophilic amino acids and interacts with lipase to form a more hydrophobic and less charged complex, which allows the lipase to be maintained in an active configuration at the lipid—water interface. It is believed that the charge characteristics of co-lipase allow it to bind to the surface of fat droplets and act as an “anchor” for lipase, allowing the enzyme to act on triglycerides. Colipase and bile salts are competitive inhibitors of substrate binding sites. The activity of pancreatic lipase is suppressed by high concentrations of bile salts, but is restored by co-lipase [8].

Identification of the functional characteristics of local areas of the intestine during lipid digestion is crucial for understanding the complete picture of digestion. The results of studying this problem are presented in a limited number of works and, moreover, are contradictory. When fats enter the duodenum, their digestion is significantly accelerated. The presence of fat in this segment of the gastrointestinal tract stimulates the secretion of cholecystokinin, which in turn regulates the secretion of pancreatic juice and bile. Cholecystokinin also stimulates the release of bile from the gallbladder [63].

The jejunum is the main site of fat digestion and absorption in poultry [50], with digestion continuing in the upper ileum [67]. There are differences in the qualitative composition of fatty acids depending on the area of the intestine [50]. Linoleic acid is absorbed in the intestinal tract starting from the duodenum, while absorption of palmitic, stearic and oleic acids begins only in the jejunum. The exact reasons for these differences are unclear, but they can partly be explained by the insufficiency of bile due to the anatomical and topographic features of the bile ducts in birds. In addition, the passage of chyme into the duodenum of chickens is very fast, and this time may not be sufficient to emulsify saturated fatty acids (68). In general, the digestion and absorption of fats is a complex process requiring adequate amounts of bile salts, pancreatic lipase and co-lipase [69]. The absence or decrease in the amount of any of these components will impair the processes of digestion and absorption.

Effect of fats on the gut microbiome of poultry. The gastrointestinal tract (GI) of broiler chickens is inhabited by a complex microbial community including fungi, archaea, protozoa and viruses, but dominated by bacteria [70]. Interactions between the organism and the microbial population have been extensively studied and analyzed by many research groups [71-75], and microorganisms are now thought to play an important role in bird nutrition, gut physiology and development [76-79]. The qualitative and quantitative composition of the microbiota and, consequently, its functionality depend on localization in the gastrointestinal tract. There is a significant difference in the taxonomic composition of the various sections of the digestive tract, so they can be considered as separate ecosystems, despite being interconnected [80)].

The microbiota plays a vital role in digestion and nutrient absorption, immune system development, and pathogen identification [83-85]. The composition and function of the microbial community varies depending on the age of the bird, localization in the gastrointestinal tract, and the ingredients consumed [79, 81, 86]. It should be noted that the taxonomic profiles described for each section of the gastrointestinal tract vary significantly across studies and depend on factors such as breed (cross), sex, genotype, diet, age, section of the intestine, use of antibacterial drugs, which makes it difficult to determine a typical profile for each department [82, 87].

The ingredient composition of the diet has an important influence on the composition of the gut microbiota [88]. In this regard, considerable attention is paid to the role of dietary components in the formation of intestinal microflora [87]. However, high-fat diets have not yet been extensively studied in terms of their effect on the microflora. Eating a high-fat diet typically results in an increase in Firmicutes and induces microbiota changes that are clearly associated with obesity and digestive disorders. In addition, the number of lipophilic bacteria (*Verrucomicrobia*, *Deltaproteobacteria*, *Ruminococcus*, *Lachnospiraceae*, *Bacteroidaceae*) increases [89]. Despite the fact that the bacteria of these groups are mostly not pathogenic or even beneficial to the body under normal nutrition, under conditions of high fat intake, the cumulative products of their metabolism can lead to multiple negative effects. A number of studies [90-93] indicate that high-fat diets increase the number of *Actinobacteria*, *Proteobacteria* and *Deferribacteres* and decrease the abundance of *Spirochaetae*. In addition, the proportion of *Collinsella*, *Streptococcus*, *Gemella* and *Elusimicrobium* is increasing. In a model mouse experiment, analysis of the gut microbiota showed that feeding a high-fat diet significantly altered gut microbiota composition, increasing *Firmicutes* abundance and decreasing *Bacteroidetes* population, resulting in a significant decrease in the *Bacteroidetes/Firmicutes* ratio. Moreover, the populations of *Clostridia* and *Deferribacteres*, *Ruminococcaceae*, *Lachnospiraceae* and *Bacteroidaceae* increased, while the population of *Bacteroidales* decreased. Thus, feeding a high-fat diet altered the qualitative and quantitative composition of the gut microbiota [94, 95]. Another study assessing the effect of fats on the microbiota found an increase in *Firmicutes* and *Proteobacteria*, and an increase in *Clostridia*, *Bacilli* and *Deltaproteobacteria* was also observed [96].

A high dietary fat content has been reported to cause an imbalance in the composition of the avian gut microbiota, resulting in increased intestinal permeability with chronic inflammation and a predisposition to food allergies [97].

Therefore, the intestinal microbiota plays an important role in digestion, and the qualitative and quantitative composition of microbial communities depends on the age of the bird, the gastrointestinal tract physiological conditions, and diet components [92]. It should be noted, however, that for the most part the results obtained so far from these experiments are contradictory or inconclusive. The difficulty in identifying specific populations of bacteria that improve digestion and productivity makes it impossible to change the microbiota to the desired one, given that causal relationships are unclear. The development of innovative tools and technologies will facilitate non-invasive monitoring of the gut microbiota [98].

Alternative sources of fats and emulsifiers in feeding broiler chickens. Rising prices for animal and vegetable fats are currently prompting the search for and use of alternative energy sources in the feeding of farm animals in order to reduce production costs [99, 100]. For this, components with a high exchange of energy can be used, such as soap stock, including soy, phosphatides, calcium salt concentrate of fatty acids, fatty diatomaceous earth and glycerin [101, 102]. The possibility of using glycerin is supported by a number of studies that have confirmed its safety and positive effect when included in the diet in an amount of no more than 5%. However, increasing the glycerol content of the diet above 10% has been shown to adversely affect the growth performance and meat yield of broiler chickens [103-105]. The main problem in the industrial use of these sources of fat is the technological difficulty of introducing them into animal feed and feed mixtures and the lack of large-scale studies on their use.

One of the factors limiting the use of high amounts of fat in the diet of broilers is the difficulty of its transformation, since in young birds the digestive tract is not sufficiently developed for the synthesis and secretion of bile salts and lipase, and the absorption and digestion of large amounts of dietary lipids is inefficient [45, 106]. In order to increase the absorption of lipids in the feed industry, emulsifying agents are used. Emulsifiers popular today usually consist of hydrophilic and hydrophobic components, which can reduce the surface tension of fat and water, reduce fat chylomicrons, improve emulsification and increase absorption of fats, replenish bile acid and lipase deficiency in the digestive tract of birds.

**2. Main properties of emulsifiers used in animal feed**

| Parameter | Emulsifier type | |
|---|---|---|
| | hydrophobic (phospholipids) | hydrophilic (special proteins) |
| Fat binding | 1:8 | 1:10 |
| The amount of stabilized fat per 1 g of emulsifier, g | 900 | 1500 |
| Assimilation of fat in the body, % | Up to 90 | 95 and more |
| The composition of the emulsifier, %: | | |
| fat | 92 | 2 |
| protein | 2-4 | 92-95 |

The main indicator by which hydrophobic and hydrophilic emulsifiers differ is the hydrophilic-lipophilic balance (HLB) (Table 2). It shows the ratio of two opposite groups of molecules - hydrophilic and hydrophobic (lipophilic). Low HLB (lipophilic) emulsifiers are more soluble in fat, while high HLB (hydrophilic) emulsifiers are more water soluble [114]. Since animals and birds consume almost 2 times more water per day than feed, an aqueous environment is formed in their intestines, which means that a hydrophilic emulsifier is preferable both in terms of efficiency and speed of action [115]. In the presence of an emulsifier, oil droplets are distributed in oil-water emulsions, which leads to efficient digestion and absorption of fat (Table 3).

**3. Emulsifiers used in the poultry industry**

| Emulsifiers | Main effect |
|---|---|
| | Natural |
| Bile acids and salts (including cholic and chenodeoxycholic acids, taurocholate) | They act as emulsifiers that disperse fat into small droplets in the aquatic environment after fat enters the gastrointestinal tract, and also increase metabolic energy, lower plasma cholesterol, and improve the absorption of dietary fats due to organic endogenous secretion [45, 65, 115, 116] |
| Lecithin | Reduces cholesterol and low density lipoproteins (LDLP) in blood serum; improves the digestibility of total energy, dry matter; enhancing the antioxidant effect of tocopherols (vitamin E), is able to increase the permeability of cell membranes, which provides better adsorption of fats and fat-soluble biologically active substances [17, 117] |
| Casein | Reduces the content of cholesterol and LDLP in the blood serum; increases digestibility [118] |
| | Synthetic |
| Lysolecithin, lysophosphatidylcholine, polyoxyethylene glycol mono- and dioleates | Conflicting results; improve the function of the liver and bile ducts; accelerate weight gain and improve feed conversion; increase growth performance and nutrient absorption [119-121] |

Natural emulsifiers are produced in the animal body and include bile acids, phosphatide concentrates, and casein [122]. Amphiphilic bile salt molecules act as emulsifiers, reducing the tension of the oil-water interface [123-125]. Casein as a natural emulsifier has become an important feed additive. The main sources of casein are skimmed milk powder and soluble caseinates, which are heterogeneous protein aggregates [126]. Soy lecithin, a by-product of soybean oil processing, which serves as an emulsifier of fats, has found wide application in practice. Manufacturers produce lecithin in several forms: defatted supplements in powder form, standard (liquid) forms, and lysolecithins (hydrolyzed lecithins) [122, 127-129].

The main manufacturers of emulsifiers include the Netherlands (FRAmelco, Orffa Additives B.V.), Germany (Berg + Schmidt, Biochem GmbH - Bredol®), USA (Archer-Daniels-Midland Company - ADM), Russia (Kemin, Apex Plus, TEXBET, Cargill, Sodruzhestvo Group).

Studies of synthetic emulsifiers have yielded conflicting results [119]. Only a few publications have reported improvements in growth performance and nutrient absorption in broiler chickens [120, 121]. It has also been found [130, 131] that emulsifiers do not significantly affect the growth performance of broiler chickens. Differences in the effectiveness of exogenous emulsifiers can be explained by many factors., e.g., the type of fat, age of the bird, lipase activity and the state of the hydrophilic-lipophilic balance.

The use of emulsifiers in broiler chickens, consisting of bidistilled vegetable oleic acid and glycerol, polyethylene glycol, ricinoleate, had a positive effect on growth, feed efficiency and lipid metabolism [112].

Thereof, many studies show the positive effect of emulsifiers on growth performance and nutrient absorption [119, 132-134], as well as on the reduction of cholesterol and triglycerides in blood serum. The addition of emulsifiers to the feed improves digestion and fat absorption in birds at an early age and results in improved growth performance [44]. Emulsifiers are widely used in nutrition, increasing lipid digestibility, thereby reducing feed intake and having a positive effect on growth performance.

Thus, fats provide the body with energy and improve the productivity of the bird. When improving the diets of broiler chickens, it is important to use alternative sources of fats. One approach to increase the amount of available fats can be the use of synthetic (lysolecithin, lysophosphatidylcholine, polyoxyethylene glycol mono- and dioleates) and natural (bile acids and salts, including cholic and chenodeoxycholic, taurocholate, lecithin, casein, phosphatide concentrates) emulsifiers. Bile salts reduce the tension of the oil-water interface, activate pancreatic lipase, and prevent its denaturation. Synthetic emulsifiers improve liver and bile duct function, accelerate weight gain and improve feed conversion, growth performance and nutrient absorption. The use of emulsifiers in the feeding of poultry makes it possible to reduce the cost of compound feed due to a smaller amount of vegetable and animal fats in the diet. This approach provides increased digestibility and absorption of nutrients both in young birds with a functionally immature digestive system and in adults and, as a result, reduces feed losses due to the intensified digestion process.

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